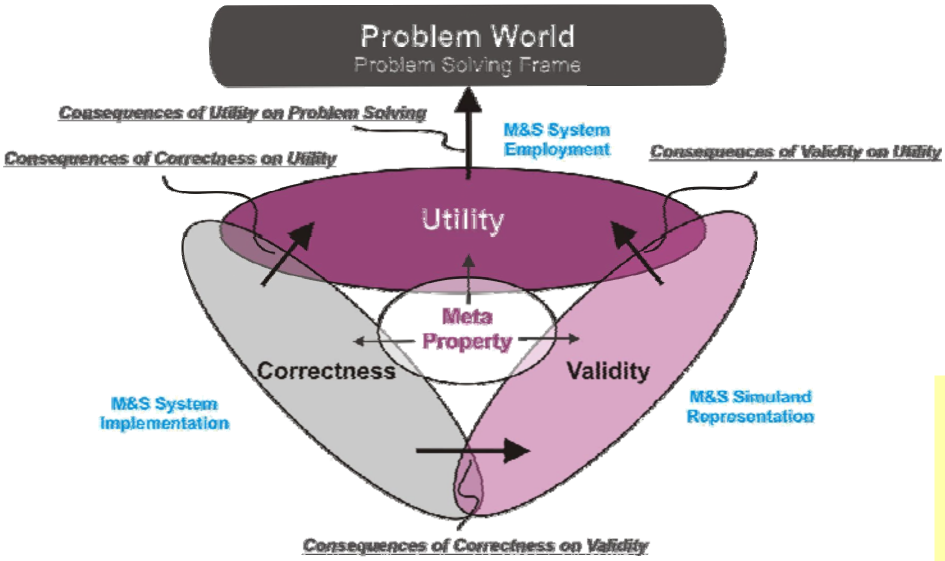
Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

Executive summary

Effective Use of Simulation Means in Collective Mission Simulation



Problem area
Mission training and rehearsal are vital to successful operation. Advances in modelling and simulation (M&S) technology now allow for Collective Mission Simulation (CMS). The Royal Netherlands Armed Forces has formulated the wish to establish a validated, reusable and interoperable CMS environment. This CMS environment must support the armed forces in adapting to operational changes as more expeditionary operations, joint and combined operations, information data management, and distribution of information. This means that the CMS must support joint and combined simulation, and be able to flexibly incorporate new simulations of new operations and technology. Therefore the CMS capability should be characterized by effective realism, interoperable systems across domains and a seamless information flow.

Description of work
Just asking for the best possible fidelity is not the solution for effective use of simulation means. The effective use consists of a balanced appraisal of utility, validity and correctness criteria. To obtain the best possible effectiveness the places in the development process are indicated where the choices have to be made for an effective use of simulations

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elements and the processes are determined which are important for reaching effectiveness. Graphical presentations are introduced that support the simulation user in assessing the effectiveness of a simulation for utility, validity and correctness. This process is illustrated with some examples of a case study for a Close Air Support (CAS) mission simulation environment.

Results and conclusions
This process defines how effectiveness can be determined and used in development and verification and validation processes of M&S assets. Practical methods for determination of effectiveness vs. utility, fidelity and correctness have been described and some have been tested. The integration of methods and processes went very well in practice. The used methods for effectiveness were suited for their purpose, but it was also clear that additional methods need to be constructed.

Applicability
The development process together with the introduced graphical presentations gives the user support to define a fit-for-purpose simulation environment to fulfil his user needs. It helps him in defining for what purpose a simulator of simulation model is suited and if its integrated CMS environment is valid for its purpose.

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ABSTRACT

Mission training and rehearsal are vital to successful operations. Advances in modeling and simulation (M&S) technology now allow for Collective Mission Simulation (CMS). The Royal Netherlands Armed Forces have exploited CMS through participation in a number of virtual exercises. The potential of collective mission simulation has been recognized and the requirement for a CMS capability was formalized. Such a capability is characterized by effective realism, interoperable systems across domains, and seamless information flow. Within the next few years the Royal Netherlands Armed Forces want to establish a validated, reusable, interoperable mission simulation environment that will support the distributed simulation of tactical and operational missions at varying degrees of security classification.

This CMS environment must support the armed forces in adapting to changing world-politics, new mission types and new technology. Examples of trends in operational changes are more expeditionary operations, joint and combined operations, information data management, and distribution of information. Major technological trends that impact the way the armed forces operate in the near future are automation and information technology, unmanned systems, better sensors, and smarter weapons. This means that the CMS must support joint and combined simulations, and be able to flexibly incorporate new simulations of new operations and technology.

In this paper we propose an approach to the development of CMS environments such that an effective use of the available assets is obtained. The effective use consists of a balanced appraisal of utility, validity and correctness criteria; all related to the intended use of the M&S assets. We first describe the engineering model from a theoretical perspective. Then we discuss how the effectiveness criteria are related and can be determined in practice. Our approach is demonstrated by a use case where part of the method has been evaluated.

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Effective Use of Simulation Means in Collective Mission Simulation

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INTRODUCTION

Mission training and rehearsal are vital to successful operations. Simulation has been a versatile tool for these purposes. In the beginning of this millennium mission training via distributed simulation was the topic of the day in the military training world. Several technology demonstrators were developed and demonstrated the technical possibilities of connecting distributed simulation environments, for example ULT-JOIND in The Netherlands. Advances in modeling and simulation (M&S) technology now allow for Collective Mission Simulation (CMS). The next step was to demonstrate that these distributed simulation environments deliver training value for the military operators. This was demonstrated in the NATO exercise First WAVE [NATO RTO task group SAS-034/MSG-001, 2007]. The Royal Netherlands Armed Forces have exploited CMS through participation in a number of such virtual exercises. The potential of collective mission simulation has been recognized and the requirement for a CMS capability was formalized. Within the next few years the Royal Netherlands Armed Forces want to establish a validated, reusable, interoperable mission simulation environment that will support the distributed simulation of tactical and operational missions at varying degrees of security classification.

Modern simulation systems often consists of many different components that are combined into a whole, referred to here as a federation, to fulfill the customers purpose. Typical building blocks are existing simulation models, hardware systems, network components, etc. A CMS system is further characterized by effective realism, interoperable systems across domains, and seamless information flow.

Not only are these mission simulation environments complex, they are often distributed over a number of facilities that are geographically dispersed over large distances. They have many users and can through reconfiguration be used for many purposes. Determining whether such simulation systems are valid for these intended uses is very difficult. When confronting the customer with questions on what fidelity is needed for these uses, the answer often is something like "it must be as close as possible to the real world". This, however, is usually either not possible or very costly.

Besides the limitation on simulating reality and costs there is a number of other elements that put limits on how useful the simulation system will be to the customer. To start, there is the factor of time. This includes not only simulation development time but also the time needed to prepare users and prepare the federation itself. The available expertise of supporting personnel can be a significant limit on final usability. Often a new federation is built by reusing many already existing components. This saves budget but hinders the possibility to tailor the new simulation system to its proposed use. Depending on the situation many more limitations may be present.

Dealing with all these limitations causes developments to strive towards the effective use of simulation means in CMS. Important for the effective use of CMS is that the simulation system adequately represents the relevant parts of reality. But reality is not the only thing that must be effective. The simulation system must also be built correctly to according specifications and be free of impeding faults. Moreover, it must be demonstrated that the simulation system really has added value and does not pose any unacceptable risks for the customer’s intended uses or exceeds the customer’s cost criteria.

Clearly, asking for the best possible fidelity is not the solution for effective use of simulation means. What is needed is an optimal weighting of all limitations dealing with much more than just reality. At several places during the development or configuration of a simulation system choices must be made to reach the goal of effectiveness.

In this paper we want to show how the best possible effectiveness can be obtained during development of simulation environments for CMS. For this it is necessary to indicate the places in a typical development process where the (design or development) choices have to be made for an effective use of simulation elements and to determine the processes which are important for reaching effectiveness.

In the next chapter we examine an engineering method, Model Driven Development for Distributed Simulation (MD3S), and the Generic Methodology for Verification and Validation (GM-VV), which are suitable to support the effective use of simulation means in CMS. In the following chapter correctness, validity and utility criteria are discussed. This is followed by a presentation of practical methods for instantiating these concepts, illustrated by some examples from a case study. Finally, some conclusions are drawn.

ENGINEERING METHODS

In Figure 1 a general engineering process model is shown. Based on the business goals (i.e. the customer's purpose), a CMS development process, as well as a verification, validation and accreditation (VV&A) process are started.

The development process assists in deriving the requirements and in designing, implementing and executing the simulation in a structured way. The VV&A process assists in determining the overall utility of the developed simulation.

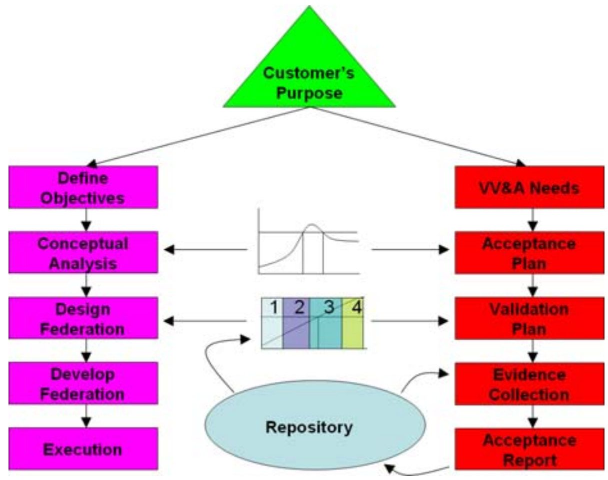

Figure 1: Development process

If the results of the engineering and VV&A processes are saved in a repository, together with the simulation components and the information about them, then these results can be reused in the future for similar analyses or to determine the suitability of these federates for other applications.

In the remainder of this chapter two development methods that can support the effective use of simulation means in CMS are discussed: the Model Driven Development for Distributed Simulation (MD3S) and Generic Methodology for Verification and Validation (GM-VV).

MD3S

For the development of distributed simulations the Federation Development and Execution Process (FEDEP) is often used. But currently there is no general agreement on one method that covers all steps of the development process. Rather, the various stages of development are supported by dedicated methods and resulting engineering models. MD3S is a proposed method to ensure an effective use of distributed simulations. MD3S unifies the FEDEP, the Model Driven Architecture (MDA) modeling architecture and the Systems Modeling Language (SysML) into one method to engineer distributed simulations. The FEDEP provides in MD3S the process basis. SysML is used to express all of the MD3S models. The MDA architecture fundamentals (i.e. Computation Independent Model (CIM), Platform Independent Model (PIM) and Platform Specific Model (PSM)) are then matched on the FEDEP. See Figure 2 for the unification into MD3S.

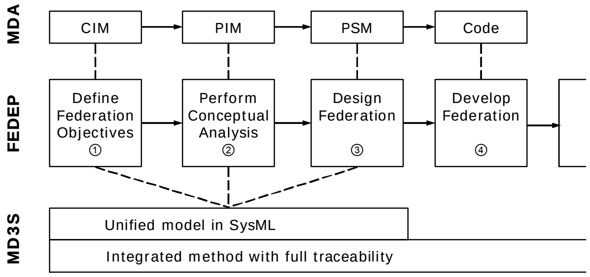

Figure 2: Unification into MD3S

This unification offers a number of advantages when trying to optimize the effectiveness of a distributed simulation. Firstly the user requirements remain clearly traceable during the different stages of specification and development. Also all aspects required for full interoperability are taking into account, including behavior specification and relation to the real-world elements that are modeled and simulated. Besides that the fact that MD3S uses a more formal specification makes it less susceptible to misinterpretation.

A more detailed description of the MD3S, illustrated by a use case, can be found in [Keuning and Gerretsen, 2008].

GM-VV

In early 2003 several European nations (France, The Netherlands, Sweden and Denmark) together with Canada started a joint research project, called REVVA. The high-level objective of REVVA was to address the issues related to the lack of a uniform and more generic approach to verification and validation of models, simulations and data, which were shared between these nation's defense organizations. To fulfill this objective the project targeted for developing a methodology, the GM-VV, to be standardized within the Simulation Interoperability Standards Organization (SISO). The GM-VV provides a full VV&A methodology covering the necessary products to be developed along with the processes and organizational elements to produce these products. The GM-VV draft standard was submitted to SISO in March 2009 and is currently in the first phase of their standardization process [SISO GM-VV PDG 2008, 2009a, 2009b].

GM-VV's VV&A vision focuses on the evaluation of the M&S system utility and confidence with respect to intended use of the M&S outcomes to solve an actual problem at hand (Figure 3). In this regard GM-VV's objective is to provide necessary information and arguments to support M&S users in the acceptance decision-making process on the utilization of models, simulations, underlying data and outcomes to satisfy their business goals.

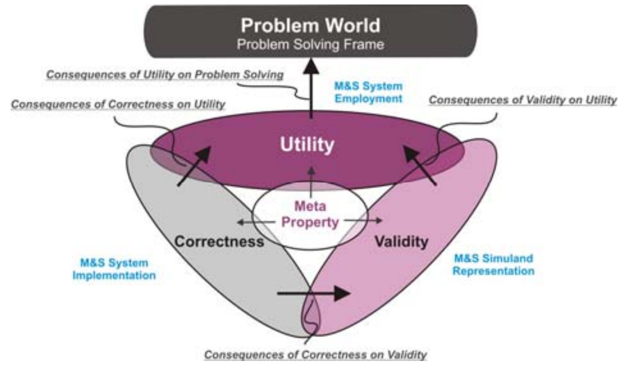

Figure 3: Utility, validity, correctness & meta properties

Within the GM-VV, verification yields evaluation of the M&S system correctness and validation yields evaluation of the M&S system validity. Acceptance decision-support yields the development of an acceptance recommendation based on the outcomes of the V&V activities complemented with an evaluation of the M&S system utility. Each of these three interrelated property classes address and provide a set of metrics for evaluating a specific part of an M&S system.

Utility properties are used to assess the effectiveness and efficiency of an M&S system in solving a problem statement in the problem world. Utility properties address three related areas: value, cost and use risk. *Validity* properties are used to assess the level of agreement of the M&S system replication of the real world systems it tries to represent i.e. the M&S system fidelity. Validity properties are also used to assess the consequences any fidelity discrepancies on the utility of the M&S system. C*orrectness* properties assess whether the M&S system implementation conforms to the M&S specification, is free of error and of sufficient precision. Correctness metrics are also used to assess the consequences of implementation discrepancies on both the M&S system validity and utility. GM-VV proposes the use of meta-properties to evaluate aspects like reliability, completeness and independency.

EFFECTIVE USE OF SIMULATION MEANS

As described in the previous section, we use the GM-VV methodology to establish that the CMS environment is valid for its intended use. There it was also shown that that use in the real world must provide utility. From utility criteria, criteria on validity and correctness can be derived using the GM-VV VV&A goal network approach. The methodology states that it must be shown that the CMS environment complies with the criteria, it does not set those criteria itself.

For the purpose of effective use of CMS assets, the criteria must be set in such a way that a valid environment is obtained for the least amount of resources.

In this chapter we indicate how to think about the various criteria and the minimum efficiency needed. Here we use a graphical presentation that, although not suited for direct practical instantiation, does show what we mean with effectiveness for utility, validity and correctness. The graphs are abstract depictions of what needs to be derived. The actual way of deriving this information can have many different forms; in the next chapter we will discuss several methods to do this.

In the graphs we present the effectiveness of a property for a given purpose as a function of how well that property is present in the CMS environment. In that curve we must find the line of minimum effectiveness. Below we give a number of examples for all three types of criteria.

Effective Utility

The utility criteria that cannot be decomposed into validity or correctness criteria are those that deal with the use of resources such as costs. In Figure 4 a typical example is given: a graph of effectiveness as a function of operational costs. This sample curve has been drawn with the assumption that there is an alternative system that also has a certain operational cost. As long as the operational costs for the current system are lower than that of the alternative, it is effective. In reality many more elements may be taken into account, e.g. that the new system is much more versatile or flexible in its operations than the alternative. In that case the operational costs might be allowed to be higher.

The horizontal dashed line in the figure indicates the value - here the operational costs - at which the system becomes effective. In this case the effectiveness vs costs curve must be above this horizontal line to be effective. The vertical dashed line is the costs value where the minimum effectiveness line crosses the effectiveness vs costs curve. This value is to be used in the utility criterion.

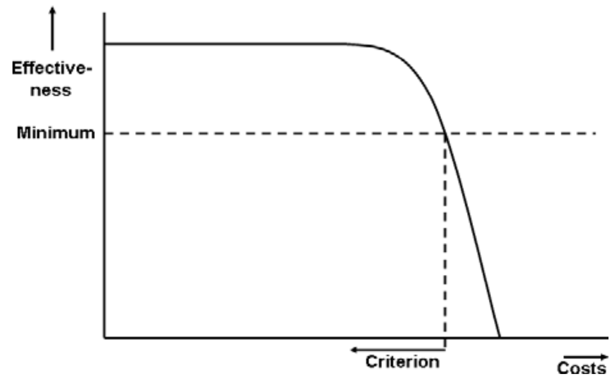

Figure 4: Utility example: Effectiveness vs operational costs.

The cost related utility criteria can be treated with effectiveness vs utility curves as shown above. Other utility criteria must be broken down into validity and correctness criteria. These are discussed below.

Effective Validity

Validity criteria indicate how well a model must correspond to reality in order to be valid. The term Effective Realism is sometimes used to indicate the amount of realism needed in a simulation in order to be effective in terms of the systems purpose. We prefer the term Effective Validity in this paper. In order for a simulation to have Effective Validity it must score higher than a minimum effectiveness level, derived from the customer's purpose.

This can, as with utility, be depicted graphically. Two examples are given below. The first is the effectiveness as a function of similarity of the virtual world compared to the real world, i.e. the fidelity, for the purpose of mission rehearsal. The curve in Figure 5 could e.g. be the precision of buildings, roads and vegetation in a database.

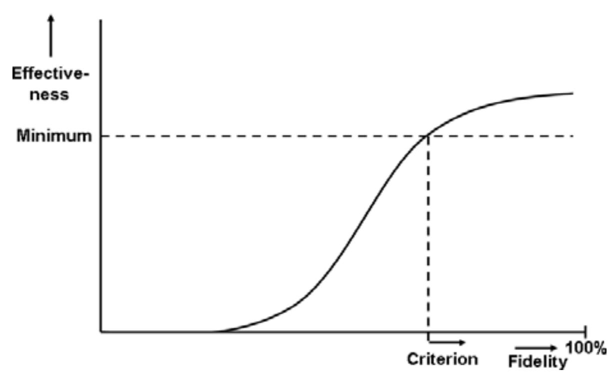

Figure 5: Validity example: Effectiveness vs precision (fidelity) of buildings for mission rehearsal.

In Figure 5 the effective validity as a function of fidelity shows that low fidelity would be of little use for the customer. If for example some roads or buildings that the pilot uses for his orientation are not available in the database, his mission rehearsal will not be effective. Also indicated is the line of minimum effectiveness. For points on the curve above this line the fidelity is considered to be sufficient in order to allow for effective use of the virtual environment for the customer's purpose. The fidelity value at which the minimum effectiveness line crosses the effectiveness curve is the value to be used in the validity criterion.

Many different shapes of the effectiveness vs fidelity curve are possible. An interesting example is the look and feel of an instrument panel for training of operators. In Figure 6 a possible effectiveness vs fidelity curve is drawn.

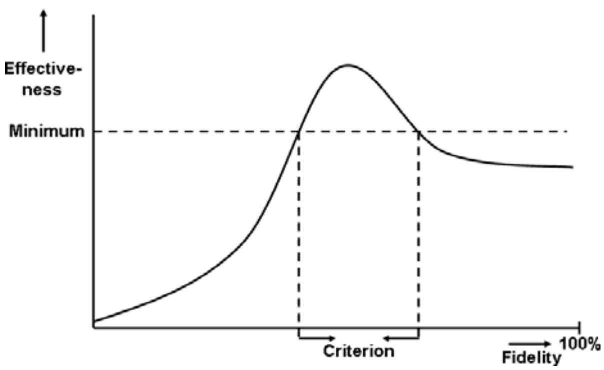

Figure 6: Validity example: Effectiveness vs interface fidelity for operator training.

Here it is assumed that the full instrument panel will consist of too many buttons and dials that a beginning trainee will get lost with low effectiveness as result. The effectiveness vs fidelity curve therefore shows a maximum. The mapping of the crossings of the minimum effectiveness line with the curve back to the fidelity axis gives a range in which the look and feel of the instrument panel is considered valid for the training of beginning operators.

Effective Correctness

Similar curves as above can be drawn for correctness. During design and production phases error or other conditions may arise such that the implementation could deviate, deliberately or accidentally, from the original specification.

In Figure 7 an example is given for the crash probability during a simulation run. The effectiveness versus crash probability curve and the Effectiveness line indicate that the system only is effective at very low probability of crashes.

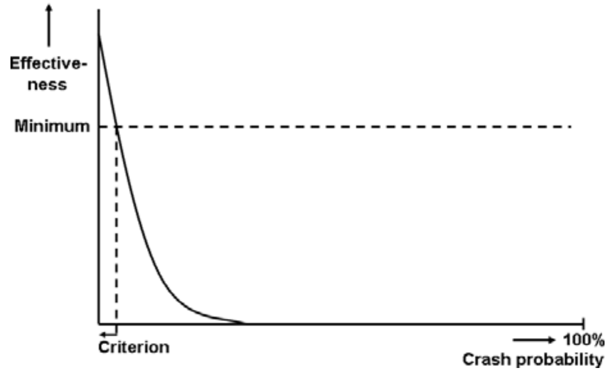

Figure 7: Correctness example: effectiveness vs crash probability.

Discussion

From the examples above it is already clear that a number of problems can arise. One of the problems is that many of such curves are needed in order to specify all needed elements of a large complex simulation system such as needed for a CMS environment. Another problem is that the shown curves only give qualitative information, nowhere are actual numerical figures given. It may turn out in practice to be difficult to get a customer to draw all these figures including quantitative data.

To add to the possibly already huge number of curves, if a customer wants a reconfigurable simulation than for all identified needed curves different versions must be drawn. For the operator training example the customer might for example want a simulator suited not only for beginning trainees, but also for those that are in an advanced state of their training. Then, several curves as in Figure 6 are needed with the maximum more towards higher fidelity for more advanced trainees.

Approach

The effectiveness for utility, validity and correctness criteria discussed above are derived and used in the process of developing a simulation. In general all needed effectiveness values are determined in the first few steps and they are used in the step where simulation components are chosen to build the whole simulation. The criteria derived from the minimum effectiveness lines are used in both the validation process and the engineering process.

In the first few steps of the engineering process utility criteria must be derived such as the shown effectiveness vs costs curve. In a typical simulation engineering process a Conceptual Model is constructed [Boomgaardt, 2008] during which all fidelity related criteria are established. It is in this phase that the validity criteria are derived by setting the minimum effectiveness in effectiveness vs fidelity curves. The correctness criteria must also be derived during the first phases.

Suppose that the customer has a number of simulation components available with partly overlapping capabilities and each with different resource usage. In Figure 8 a situation is shown where four different models are available for a given role in a large simulation. The first model is a very simple model with low costs, immediately available and does not contain secret algorithms or data. The fourth model is very expensive, takes considerable time to configure and can only be used by specific personnel. The other two models fall in between the first and fourth model in terms of costs, time and needed security.

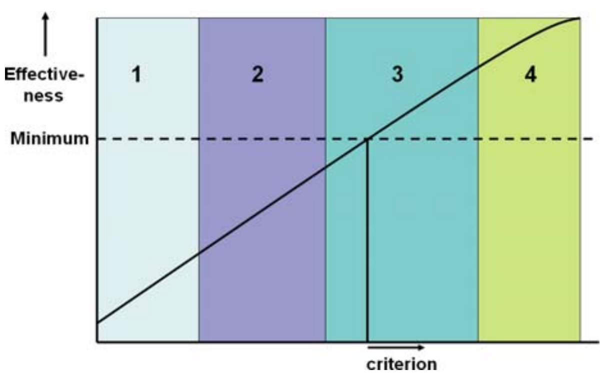

Figure 8: Available simulation components mapped on an effectiveness curve.

Given the effectiveness curve and the minimum effectiveness value, it becomes clear the two of the available simulation components can be configured to be effective given the users purpose. Although the fourth model is better suited than the third, it also costs more, takes more time and involves more special personnel.

Of course, the effectiveness of the simulation as a whole depends on many criteria. For each criterion available simulation components must be mapped on the effectiveness curve to find those that score above minimum effectiveness.

The problem is that this overall effectiveness is in general not always attainable because of overall limitations. Cost is a clear example of a limit that forces choices in components that drive the overall effectiveness down. Also available time, needed expertise and, especially in military application security issues, can put a spoke in the developers wheels.

This might mean that some aspects of a simulation will be below the determined effectiveness limit while other aspects score above this limit. If that is the case, the aspects that are not up to standards cause the overall customers purpose to not be met. The simulation might, however, still be suited for some parts of the customer's purpose. The forced choices during the development of the simulation can be made such that the best possible effectiveness can be reached. All choices where the utility falls below the effectiveness must be recorded and communicated back to the customer and users as limits on the original purpose.

Optimal effectiveness is obtained when all influencing factors are taken into account and the negative impact on effectiveness of forced choices for components that score below minimum effectiveness are minimized. The impact of the influencing factors may differ. This impact must be derived based on the customer's purpose and the contribution to that purpose. The estimated risk of using a component that does not score above the effectiveness value is an important issue to take into account.

PRACTICAL METHODS FOR EFFICTIVE USE OF SIMULATION MEANS IN CMS

The graphical effectiveness curves as presented in the previous section need to be instantiated in practice. In this section a number of ways to do this are discussed and illustrated in italic by some examples from a case study we performed in December 2008.

The setting for this test case has been a Close Air Support (CAS) scenario in which a Forward Air Controller (FAC) team cooperates with two F-16 pilots. This scenario has been executed for two different purposes:

1- training; and

2- mission rehearsal

The overall aim was to demonstrate how to create simulation environments which are fit for purpose and to demonstrate the potential of Collective Mission Simulation for in the Royal Netherlands Armed Forces, see [Voogd, 2008]. An assessment of the validity/effectiveness/usability of the federation for CAS training and mission rehearsal to prepare operators for theatre has been made.
The case study performed in 2008 concerned an early prototype, the results of our effectiveness study will be used to guide further developments. The simulation was distributed over two facilities, the Fighter 4-Ship F-16 at the NLR facility in Amsterdam and the FAC

team at the TNO facilities in The Hague, both in the Netherlands.

In general it is not so easy to determine the many needed effectiveness criteria, given a purpose and a system.

Phases: define objectives and perform conceptual analysis

During the first two phases of the engineering process (define objectives and perform conceptual analysis) all known methods for requirements elicitation may be employed. One particularly helpful method may be to use Subject Mater Experts (SMEs). For complex systems many different SMEs may be needed. SMEs with a large experience with similar systems are likely to be able to set criteria. On the other hand SMEs specialized in human factors may be used to derive the optimum system configuration for e.g. training systems. It may turn out that good systems need not be realistic at all!

In these phases it may prove useful to present stakeholders with ranges of examples of (parts of) the future system. These ranges can go from highly abstract to very realistic. The stakeholders must then pick which system they deem will be just good enough for their purpose. For example, the MD3S method discussed earlier provides an abstract view of a real system where all sub-systems can be explored from an abstract to a detailed level. For each relevant "dimension" this may be helpful when determining which level is just good enough.

Users may also be presented with existing similar systems to point out elements which need to be improved and which may be downgraded.

In the case study we determined with an SME, a former F-16 pilot, the minimum fidelity required for the F-16 simulation. For the CAS training it is important that the pilot can take the right decisions and can timely perform the right actions in the right sequence. If he is doing this correctly then the training is successful. Therefore the most important elements of the simulation are the systems and symbology that assist the pilot in the correct delivery of the weapon. The actual fly-out of the bomb and the impact of the explosion are not important for the training. Since the training focuses mainly on the procedures, the exact geographical location where it is performed is of less importance.

For the CAS mission rehearsal the result of the mission, i.e. the impact of the dropped bomb, is important. Therefore a higher fidelity model of the weapon is required, so that the fly-out and disturbances during the flight are also represented. Besides that a realistic representation of the geographical area of the mission is required. These requirements are additional upon the requirements on the systems and symbology that already applied for the training.

Based on these requirements the SME together with simulation specialists made a first estimate of what is needed in the simulation. Using the MD3S method a hierarchically structured schematic model in SysML of an F-16 and its components was constructed. For each of these components (e.g. flight dynamics, avionics, sensors, weapons) the requirements based on the intended use of the simulation where translated into the required detail for these components.

Phases: design and develop federation

During the design and develop phases an important method of determining effectiveness is the use of prototypes. In a spiral development type of process a series of prototypes can be built and tested. It need not be one complete prototype; it may also be parts of the final system. The stakeholders can test the prototypes and indicate what is missing, what needs to be improved, what is good enough and even what might be downgraded. A typical way of doing this is by running (parts of) scenarios and use questionnaires or interviews to let stakeholders give scores. Where possible, objective, i.e. not using humans, validation tests may be employed to find elements that need to be upgraded and those that are good enough. The test and questionnaires or interviews should address all appropriate criteria from utility, validity and correctness.

During the test case evaluation in December a prototype of the simulation system was used. All elements of the simulation were present, but some were still in early versions. The simulation system was tested with real professional operators and trainers for the Royal Netherlands Armed Forces. Before and after each experiment a questionnaire was filled in by the operators, the trainers and the present simulation specialists. The questionnaire covered all major aspects of the simulation system and left room for remarks and additions. For each element it could be filled in how important it is and how much fidelity is needed.

From the questionnaires it became clear which elements of the simulation are already in good shape and which elements needed enhancements. One of the elements that clearly needed to be improved was the distributed brief and de-brief facility. For other elements it turned out that their required fidelity as, *sometimes surprisingly, not as important as initially thought. For example the training and rehearsal value was not too depending on the fidelity of the presented damage.*

Phase: execution

Also during execution effectiveness can be obtained by taking certain measures. In distributed simulation, effectiveness for the individual simulations may not result in overall effectiveness, here called *Collective Effectiveness*. Effectiveness may for example be more dependent on having all players getting a fair amount of utility instead of having some players get most benefits while others are just there for a support role.

For validity the following two examples make clear that fidelity may not be all that important in order to reach collective effectiveness. During simulation experiments with many geographically dispersed simulators having largely varying fidelity levels, it turns out that the absolute fidelity of terrain databases is less important than having correlated terrain databases for each asset.

Similarly, the fidelity of models that handle damage due to weapon use turns out to be less important than having models that are trusted by all participants. Even if those models have low fidelity, for many purposes effectiveness is reached as long as those models are "neutral" in their working and their verdict is adopted by all players.

For correctness the following is an example that may be taken into account. If a collective simulation consists of many different parts that must all work together to produce effectiveness, the correct working of each part must adhere to stringent standards due to the interdependency of the parts. However, for some purposes in e.g. collective simulation such as training of operations with many different types of equipment, it may not be a problem if now and then a simulated piece of equipment becomes (temporarily) unavailable due to correctness problems in the software. In real life it can also happen that equipment breaks down and needs to be fixed before it can be used again.

Use of criteria during decision making

Above ways are described in which effectiveness is influenced in practice or effectiveness criteria can be established. In order to make decisions on which assets to use in a simulation it is necessary to know how much resources are involved in changing (upgrading and possibly downgrading) these assets. Then, as described in the discussion section of the previous chapter, all alternatives plus the costs associated with changes and the risks of non-effectiveness must be taken into account and the most optimal combination of assets and changes must be determined.

CONCLUSIONS

In this paper we have described how effectiveness can be determined and used in development and verification and validation processes of M&S assets. Practical methods for determination of effectiveness vs utility, fidelity and correctness have been described and some have been tested. The integration of methods and processes went very well in practise. The used methods for effectiveness were suited for their purpose, but it was also clear that additional methods need to be constructed.

REFERENCES

Boomgaardt et. al (2008), NATO-MSG-058 Conceptual Modeling for M&S, 08F-SIW-038, SISO SIW.

Keuning, M.F.R. and Gerretsen, A. (2008). Model driven Development for Distributed Simulation using SysML, *I/ITSEC conference 2008, paper 8187*, Orlando, FL, USA

NATO RTO Task group SAS-034/MSG-001 (2007), Mission Training via Distributed Simulation and First WAVE: Final Report, *NATO RTO Technical Report, RTO-TR-SAS-034*

SISO GM-VV PDG (2008), Guide for Generic Methodology (GM) for Verification and Validation (VV), and Acceptance of Models, Simulations, and Data, Recommended Practice Guide, SISO-GUIDE-00X.2-200x-DRAFT-v1.1

SISO GM-VV PDG (2009b), Guide for Generic Methodology (GM) for Verification and Validation (VV), and Acceptance of Models, Simulations, and Data, Reference Manual, SISO-GUIDE-00X.3-200x-DRAFT-v1.0.3

SISO GM-VV PDG (2009b), Guide for Generic Methodology (GM) for Verification and Validation (VV), and Acceptance of Models, Simulations, and Data, Handbook, SISO-GUIDE-00X.2-200x-DRAFT-v1.2

Voogd, J.M. et al. (2008), Collective Mission Simulation in The Netherlands, Key Problems & Solutions, I/ITSEC conference 2008, paper 8002, Orlando, FL, USA